Braz J Oral Sci.
April/June 2009 - Volume 8, Number 2

Original Article

Evaluation of three radiographic methods for detecting occlusal caries lesions

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Abstract

Aim: To compare, *in vitro*, the performance of three radiographic methods for the detection of occlusal caries in permanent teeth. **Methods**: A total of 96 extracted molars with no apparent occlusal cavitation were selected, they were photographed and radiographed under standardized conditions using conventional E-plus films and two digital systems, CDR and Sidexis. Two examiners analyzed all films and images, recording the presence and lesion depth. One quarter of the teeth were re-examined for intra- and interexaminer agreements. The teeth were subsequently bisected and examined under a stereomicroscope. The intra and interexaminer agreements and the diagnostic performance (sensitivity, specificity, accuracy and the area under receiver operating characteristic, ROC curve) of each method were evaluated. **Results**: Out of 96 occlusal surfaces, 41 were sound, 31 had lesions in enamel, and 24 had dentin lesions. Weighted Kappa values for intraexaminer agreement varied widely, depending on both the observer and method. The interexaminer agreement was higher for the digital images than for the conventional films. The area under the ROC curve for enamel and dentin caries (at D1 diagnostic threshold) was 0.55 for films, 0.60 for Schick and 0.54 for Sirona, which were not significantly different from each other. **Conclusions**: Digital images presented better results of interexaminer agreement; however, no additional effect in the diagnostic performance could be observed in comparison to conventional films.

Keywords: digital radiography, dental caries, ROC curve, diagnostic test.

Introduction

Advances in radiographic detection methods include the development of several digital radiography systems for dental use[1-5]. These systems have shown a number of advantages over conventional radiography (film-based images), but their incorporation into dental offices has occurred slowly. Several digital radiographic systems are available for the clinicians, who are replacing conventional radiography[1,4]. However, very little data is available on the diagnostic differences between intraoral digital systems and conventional radiographs to detect occlusal caries lesions[4,6-8]. In addition, there are few studies evaluating the diagnostic efficacy of charge-coupled device (CCD) based sensor systems for this purpose[4,7]. It is; therefore, necessary to continually evaluate these methods with regard to their clinical performances in order to obtain information that could help the dentists in selecting the best system for their clinical purposes.

Received for publication: December 22, 2008
Accepted: May 18, 2009

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The aim of this study was to compare the accuracy of conventional radiographs and two different digital systems – CDR and Sidex – for detecting caries lesions in occlusal surfaces.

Material and methods

The research protocol was reviewed and approved by the Ethics Committee in Human Research of Faculdade de Odontologia of Universidade Estadual de Campinas (Unicamp), under the protocol #028/2004.

For this study, 96 permanent molars without fillings extracted, which had been stored in 10% buffered formalin, were selected. None of the teeth had any macroscopic occlusal cavity formation or clinically visible proximal caries, but presented several degrees of fissure discoloration. The teeth were first cleaned with prophylaxis brush and pumice slurry, rinsed with air/water spray and mounted in plaster blocks in sets of three teeth, simulating anatomic positions. The occlusal surfaces were photographed (4× magnification) and one site was chosen *per* tooth. Then, they were radiographed under standardized conditions and the exposures were made using a Trophy General Electric GE 1,000 Intra-oral X-ray unit (General Electric Company, Crown Point, IN, USA), operating at 70 kVp and 8 mA and using exposure time of 0.25 second for conventional film and 0.08 for digital systems. The blocks of teeth were placed in a holder device specially designed to provide standardized projection geometry during exposure. The focus-film distance was 21 cm and a 15-mm thick acrylic material equivalent to soft tissue was placed, between the cone end and the blocks of teeth.

The radiographs were taken using a conventional dental film (Ektaspeed Plus-Eastman Kodak Co, Rochester, NY, USA) and two different digital systems, Sidexis (Sirona, Bensheim, Germany), which uses a sensor with CCD technology, and CDR (Schick Technologies, NY, USA), which uses complementary metal-oxide semiconductor (CMOS) technology.

The films were processed in a Dürr automatic unit (1330, AC 245 L, Bietighein-Bissingen, Germany), mounted in frames and examined using a viewing box and a dental X-ray viewer (4× magnification).

The digital images were displayed on a SVA 17-inch monitor screen (Dell Computer Corporation, Austin, TX, USA). The conventional radiographs and the digital images were examined by two independent and previously calibrated observers, both experienced researchers in caries diagnosis. Selected sites on each photograph were used to locate the precise investigation site on the radiograph in a mesiodistal plane. The occlusal caries depth was assessed using a rank scale with the following criteria[5]: 0 = no caries, 1 = radiolucency extending to the outer ½ of the enamel, 2 = radiolucency extending to the inner ½ of the enamel, 3 = radiolucency extending to the outer ½ of the dentin and 4 = radiolucency extending to the inner ½ of the dentin.

One week elapsed between individual sets of recordings. After this interval, 25 teeth were re-examined to assess the intra- and interexaminer agreement. The diagnostic performance of each observer with the three recording systems was compared to the histological diagnosis (gold standard).

For validation of the true presence or absence of caries, the teeth were sectioned in a buccolingual direction through the selected investigation site using a Silverstone Taylor microtome (Scifab, Lafayete, Colo, USA). The histologic examination was done with a stereomicroscope (Model BH2, Olympus Optical Co., Ltd., Tokyo, Japan) at a 40× magnification and performed by the two observers (joint decisions). Both sides of each tooth section were examined. Caries was defined as being present when demineralization seen as a white or discolored (yellow/brown) area was observed. The following classification criteria were applied: 0 = no caries, 1 = demineralization extending to the outer ½ of the enamel, 2 = demineralization extending to the inner ½ of the enamel, 3 = demineralization extending to the outer ½ of the dentin and 4 = demineralization extending to the outer ½ of the dentin.

Statistical analysis

Intra- and interexaminer agreements for the X-ray methods were assessed using weighted Kappa statistics[9]. The diagnostic performance for occlusal enamel or deeper (cut off ≥ 1) was evaluated using the parameters sensitivity and specificity and area under receiver operating characteristic (ROC) curve (Az), having the histological ratings as a gold standard (at D1 threshold: caries in enamel in histological sections was considered "positive"). To compare the sensitivity, specificity, accuracy, and area under the ROC curve (Az) among the methods, a bootstrap sampling procedure was used. A bootstrap sample was obtained by randomly selecting specimens with replacement, preserving the percentages of true positives and negatives in the sample distribution. The estimates were obtained for each of the 1.000 bootstrap samples for each method, and the difference between the methods was calculated. Bootstrap sampling allows p-values and confidence intervals to be generated for the differences between methods. Area under the ROC curve (Az), an indicator of overall diagnostic performance which does not require cut offs for the diagnostic methods, was computed using the c-statistic from logistic regression models for each examiner and method. Area under the ROC curve was computed using the c-statistic from logistic regression models for each examiner and method at a 5% level of significance.

Results

According to the histological examination, 41 teeth were sound, 31 had caries confined to the enamel, and 24 had caries in dentin.

The intraexaminer agreement mean values for the two examiners, using weighted Kappa, were respectively: 0.79 and 0.75 for conventional film (CF), - 0.01 and 0.66 for CDR, and 0.40 and 0.67 for Sidexis. Interexaminer agreement was higher for the digital images (0.90 for CDR and 0.85 for Sidexis) than for the CF (0.57).

The results of the diagnostic parameters are summarized in **Table 1.** In general, CDR had the highest sensitivity, specificity, diagnostic accuracy, and area under the ROC curve. CDR had significantly higher sensitivity than Sidexis (p = 0.0397). No other differences among the three systems were statistically significant (p > 0.05).

Table 1. Diagnostic performance for enamel and dentinal caries diagnosis of the three radiographic systems and two examiners, expressed as sensitivity, specificity and accuracy

Method	Sensitivity	Specificity	Accuracy	Az
CF	0.20[ab]	0.89[a]	0.49[a]	0.55[a]
CDR	0.27[a]	0.91[a]	0.55[a]	0.60[a]
Sidexis	0.15[b]	0.91[a]	0.48[a]	0.54[a]

CF: conventional film. Different superscript letters indicate statistically significant differences among the diagnostic methods (p < 0.05); Az: area under the ROC curve.

Discussion

The literature is still scarce in studies evaluating the accuracy of Sidexis and CDR dental digital imaging systems, for detecting occlusal caries lesions[4,7,10]. Studies in this field were mainly carried out using a storage phosphor digital system[5-6,10-12] (Digora; Soredex, Helsinki, Finland). The majority of the studies comparing these two digital systems evaluated their performance for detecting proximal caries lesions[3,8,13].

Although there is no other study in literature that compares these two systems for detecting occlusal caries lesions, data from other ones have demonstrated significant differences in the diagnostic accuracy among digital radiographic systems. The mean value of Az for the Sidexis system (0.54) in the present study was lower than that obtained by Hintze et al.[12] (0.8 to 0.92) and Hintze[7] (0.75 to 0.79). However, in these previous studies, the authors considered that the cut off for the presence of disease was caries in dentin, which naturally increases the diagnostic performance of the radiographic methods. Data of some studies have demonstrated that Sidexis presents poorer contrast in its images of dental structures, hindering the differentiation of relevant details[8,14-15]. To achieve optimal image clarity of the areas of interest, these authors modified the images by adjusting contrast and brightness, possibly influencing the performance of the method, but this was not done in the present study. In addition, data of another study[14] show that the Sidexis system underestimated the depth of proximal caries lesions by 51%, when compared with the gold standard examination. According to Pfeiffer et al.[15], this might have happened due to the automatic optimizing of the Sidexis system, reducing the 12-bit digitized image into a 8-bit displayed image.

Regarding CDR, a new version of this equipment was introduced in 1998[2] which has a sensor with a smaller pixel size and uses the Active Pixel Sensor (APS) and CMOS technologies. This change improved the physical performance of this direct digital radiographic sensor when compared to the earlier generation[2]. Analoui[1] suggested that, based on the inherent characteristics of the new technologies used in the CCD sensors, they have the potential to surpass film in virtually every relevant aspect. Studies on the performance of this new model of CDR for detecting carious lesions are needed, in order to assess whether they are better than conventional radiograph for this purpose.

The poor performance of the radiographic methods evaluated in the present study may be attributed to several reasons. It is well known that a radiograph is unable to detect initially demineralized occlusal enamel and dentin lesions, resulting in low sensitivity[10-11,16-23].

In the present study, of all teeth presenting caries lesions, 56.3% had caries in enamel and 36.3% presented carious lesions extending to the outer half of the dentin, and only 7.4% of the lesions were located in the inner half of the dentin, which can lead to underestimate the performance of the methods. There are two aspects of the study design that limit the interpretation of the results. First, as no metal strip was fixed to the pre-selected site by tape before exposure to ensure its precise identification, the location of the clinical site in the radiographic examination was not precise. This could have allowed the observers to evaluate different sites from those selected in the individual photographs. Second, the histological sections were obtained in a buccolingual direction through the selected investigation site only. Although the study of Ekstrand et al.[16] used the same methodology, the majority of the studies evaluating the performance of radiographic methods in detecting occlusal caries lesions serially sectioned the teeth in various sections, in the buccolingual direction[3,6,12,14,17,19,24-25]. It is obvious that in these studies, the probability of detecting a carious lesion was higher, and the determination of the diagnostic performance of the method was probably more accurate. However, in daily clinical practice, the dentist frequently wants to know the radiographic extent of a clinically detectable lesion in a single site in the occlusal surface. Therefore, further studies to evaluate the site-specific performance of radiographic methods are recommended.

Although in this study brightness and contrast of the images were not enhanced as in previous studies, it seems that there are no significant differences in the accuracy between enhanced and unenhanced images[7,8]. In addition, it appears that in clinical practice, dentists use the enhancement facilities of digital radiographic systems (brightness and contrast manipulation) very differently, and enhancements not properly used may actually reduce diagnostic accuracy[26]. However, further studies should be carried out to assess whether the management of these variables can influence the accuracy of the methods tested herein[26-30].

The present study demonstrates the diagnostic equivalence of two digital systems with conventional film using similar viewing conditions. These findings agree with the data presented by other studies, which found out that digital intraoral radiographic systems seem to be as accurate as current conventional dental films for detecting occlusal caries lesions[5,8,13].

In conclusion, digital images presented better results of interexaminer agreement; however, no additional effect in the diagnostic performance could be observed in comparison to conventional films.

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